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Application of a multibeam echosounder for the digital imaging of the bottom relief of seabeds and rivers

Zastosowanie echosondy wielowiązkowej do cyfrowego obrazowania rzeźby dna mórz i rzek

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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Abstract: In this paper, the possibilities for detailed digital mapping the bottom relief of seabeds and rivers using a multibeam echosounder are described. The paper is based on the results of many years of experience, with utilitarian and research work carried out by the Maritime Institute in Gdańsk. Selected examples of the digital bottom models of the Baltic Sea and the Vistula River are presented. The obtained results give the full picture of a hitherto unknown bottom relief.

Keywords: seafloor mapping, digital terrain model, remote sensing, MBES

Streszczenie: Opisano możliwości użycia echosondy wielowiązkowej do szczegółowej, cyfrowej rejestracji rzeźby dna mórz i rzek. Podstawę pracy stanowią rezultaty i doświadczenia uzyskane w wyniku wieloletnich badań utylitarnych i badawczych przeprowadzonych przez Instytut Morski w Gdańsku. Zaprezentowano wybrane przykłady cyfrowych modeli dna Morza Bałtyckiego oraz rzeki Wisły. Uzyskane rezultaty dają pełny, do tej pory nieznany, obraz rzeźby dna.

Słowa kluczowe: kartowanie rzeźby dna, cyfrowy model terenu, teledetekcja, MBES

Introduction

Light Detection and Ranging (LiDAR), mainly using ASL (Airborne Laser Scanning) and TSL (Terrestrial Laser Scanning), is a good method for surveying a land relief (*vide* Wehr & Lohr 1999). A digital terrain model can then be generated based on LiDAR data (Axelsson 1999). This is useful, inter alia, to evaluate the state and the changes of a seashore (*inter alia* Sallenger et al. 2003, Saye et al. 2005, Sitkiewicz et al. 2015). Nevertheless, effective LiDAR surveying of a relief of a river or sea bottom is often not possible, due to the limited capabilities of the method (Gao 2009). Therefore, we need to develop a different research tool to study a subaqueous relief.

The results of a bottom survey obtained by using a multibeam echosounder (MBES) are similar to those of a survey conducted by LiDAR on land. It also provides data to create a digital terrain model (*vide* Szefler et al. 2015, Wróblewski et al. 2015), with a high resolution (accuracy of higher than 10 cm), and many others opportunities for further research.

The aim of the paper is to summarise the possibilities of using a multibeam echosounder, based on the results of the utilitarian and research work that has been conducted by the Department of Operational Oceanography at the Maritime Institute in Gdańsk.

Briefly overview of the method

Conducting a correct depth measurement requires the identification of three variables: the position of the measurement, the depth at that position and the time of the measurement. Accurate positioning (better than 0.5 m) can now be provided by a modern satellite positioning system, which can be integrated with the appropriate navigation systems and specialised collection programs (in real time) to compile the data.

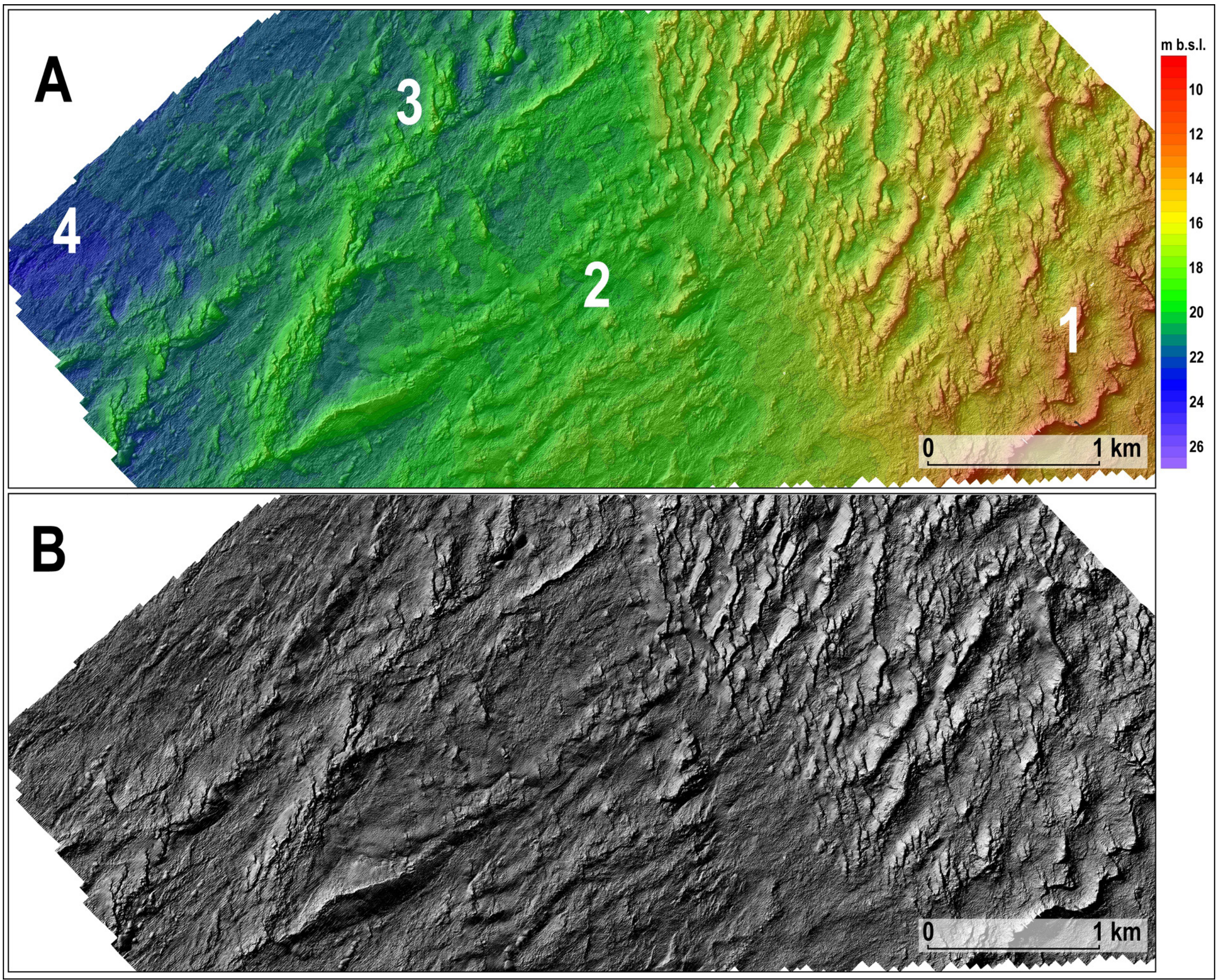

Fig. 1. Fragment of the open sea bottom in the Southern Baltic. A – bathymetry of the background of a 3D relief: 1 – exhumed relict of a moraine relief; 2 – relict relief partly covered by sand; 3 – sand waves; 4 – sandy accumulation platform. B – raised-relief map.

In the 1920s, after centuries of relying on plummet measurements, a single beam echosounder (SBES) was first introduced for general use. It has revolutionised the measurement of depth. Today, we are witnessing the next revolution that was initiated by the introduction of the multibeam echosounder (MBES) by Reson in the 1980s (Reinking 2010).

The MBES provides accurate measurements of the depth of whole sections of the bottom, with full coverage and a resolution up to 10 cm, both horizontally and vertically. A cloud of points with coordinates (x, y and z) are obtained by the measuring, and provide a basis for compiling digital terrain/bottom models. The continuing miniaturisation of the equipment now allows for the installation and calibration of the whole measurement system on a small hydrographic pontoon. Currently, the main limitation of the method is merely the water depth.

Multibeam sonar measurements provide new opportunities for research and a new quality of the analysis and evaluation of the morphological conditions and the dynamic state of a bottom. This includes: its mapping; the detection of objects of an anthropogenic origin; increased diligence; inventories and monitoring of hydraulic structures, etc. Presently, multibeam sonar measurements of a bottom have become the basis for research conducted at sea and on inland waters, in many areas of science and industry.

Besides the depth, the multibeam echo sounder provides information about the intensity of the signal reflected from the bottom, and the shape of the signal passing through the water column. This enables the researchers to identify sediment types, and to detect schools of fish as well as sources of gas outflows from the bottom and gas leaks from pipelines. MBES is therefore a powerful research tool for a number of scientists and engineers.

Additionally, a digital bottom model is usually supplemented by information about the character of the bottom surface. A side scan sonar image is basically the equivalent of an aerial photography on land. By analysing both the digital terrain

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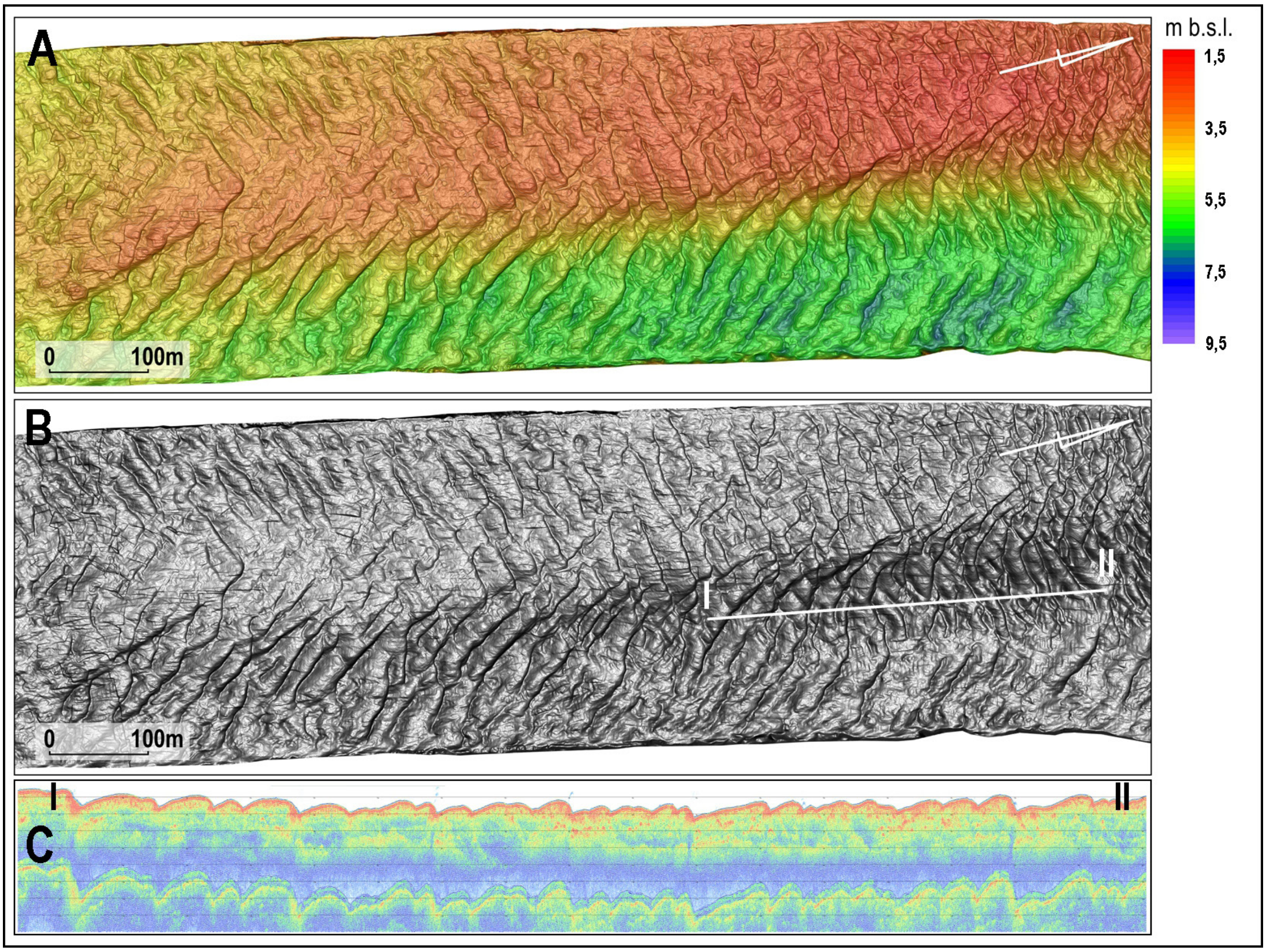

Fig. 2. Bottom of the mouth section of the Vistula. A - bathymetry of the background of a 3D relief. B – raised-relief map. C – record of the parametric sub-bottom profiler.

model and a sonar image, we are able to recognise the nature of a bottom surface, as well as to indicate objects and recognise its landforms.

Knowledge about the relief and the nature of the bottom surface is also complemented by the recognition of its inner structure, from a depth of a few to several meters, using high resolution seismic profiling. In this way, images of subsurface structures can be obtained, at a resolution which allows for the identification of the rocks and their spatial relationships.

Examples of results

We will present two examples of digital terrain models. First, an open part of the Baltic Sea, located near the city of Jarosławiec in Poland, is shown in Figure 1. Also, the digital bottom model of the mouth section of the Vistula River is shown in Figure 2. These fragments are fully covered by multibeam sounder and side sonar images; and seismoacoustic profiling has also been performed.

An exhumed postglacial relief is clearly visible on the eastern part of the Jarosławiec field (Fig. 1). This postglacial relief is covered by a thin layer of modern marine sand, as well as sandy waves. The image of the bottom of the Vistula Canal (Fig. 2) shows a richness of form with a series of mega ripple marks moving along the surface of the sandbar and on the water pools.

The first detailed research was performed on the Vistula Canal and the Jarosławiec field (*vide* Lisimenka et al. 2013, Szefler et al. 2011) and the presented examples provide actual and a full pictures of the bottom relief. Before now, this result would not have been possible to achieve. Profiles, which are conducted very densely by a single beam echosounder, with highly accurate positioning under great hydrodynamic conditions, are the good material to generate a valuable digital bottom model too (*vide* Rudowski & Gajewski 1998, Gajewski et al. 2004), however, an interpolation between the profiles was necessary; therefore, the final result is not a full picture of the bottom relief.

The MBES system is a great tool to use in order to create a detailed digital imagining of the bottom relief. However, the main limitations of this method are the depth of the water and the accessibility of the area for a survey vessel. Using an MBES is difficult in the more shallow parts of the nearshore, and in weedy or too shallow parts of a river channel.

Conclusions

The MBES method, supported by a sonar images and a seismoacoustic record, gives us the ability to accurately describe the bottom surface of seas, rivers and lakes, and in a sense to explore them at a new level that is comparable to land exploration. Besides identifying the nature of the surface, and its relief and structures, we can discover the processes that contributed to their current state and the nature of the bottom, which significantly increases the possibility for correct reasoning, and for the planning and carrying out of further work and research.

The advantages we have demonstrated above indicate that current digital imaging using a multibeam echosounder is widely regarded, at the Maritime Institute in Gdańsk and elsewhere, as a routine method for all utilitarian and research work conducted on the sea/river bottom.

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